# Preface

In the recent years we have seen an increasing interest in many areas of research related to bioenergy. Bioenergy is renewable energy, and it is produced using biological sources such as, agricultural products and residues, forest products and residues, energy crops and other types of biological waste. The increasing interest in bioenergy has been motivated by its potential to become one of the future energy sources of USA. This in return is expected to reduce the nation's dependency on fossil fuels, and to have a positive impact on the economy, environment and society. Investments in and use of bioenergy have been encouraged by a number of legislations at the federal and state levels. For example, the Renewable Fuel Standard in the Energy Independence and Security Act of 2007 requires an increase of the minimum annual level of renewable fuels used in U.S. transportation fuel from 9 billion gallons in 2008 to 36 in 2022. These targets are expected to be met through a variety of biofuels, among which, grain ethanol and cellulosic ethanol will be major contributors.

Despite the increasing interest, the economic viability of bioenergy and its future have been questioned and challenged for the following reasons. The production of traditional, first-generation biofuels relied on the use of edible products such as, corn and soyabean. This fact stirred the national debate of food versus fuel. Many of the existing conversion technologies are in the pre-commercial stages. Most non-food feedstocks have not reached cultivation status where they may be considered commodity products. Non-food feedstocks are bulky and difficult to transport, thus, the corresponding delivery costs are high. Most of the vehicles we use cannot handle blends with more than 10 % ethanol. Despite the challenges faced today, we believe that investing in bioenergy is very important. The goal of this handbook is to present some of the state-of-the-art developments and tools to help the industry overcome the economical challenges. A number of chapters in this handbook present optimization and simulation models to optimize biomass transportation, and bioenergy supply chain. A few chapters present results from life-cycle cost analysis of different types of biofuels. One of the chapters proposes a bi-objective optimization model that determines the optimum allocation of marginal land and crop land for biomass cultivation and supply chain optimization.

A number of case studies are presented that illustrate the impact of these tools in making bioenergy an economically viable energy option.

Let us provide a short review of the logistical challenges the industry has been facing in the past two decades. The production of traditional, first-generation biofuels (ethanol) relied on the use of corn and soybean. Most ethanol plants were located in the middle of corn fields and within a short radius from their supply. These location decisions were motivated by the high costs of transporting biomass. The limited amount of biomass available within this collection radius did not justify investments on large-scale biorefineries. As a result, traditional biorefineries have low production capacity and have not benefited from the economies of scale associated with high production volumes. The second-generation biofuels utilize agricultural and forest waste and energy crops as feedstock. The logistical efforts with loading, unloading and transporting these types of feedstock are higher since these types of biomass feedstock are bulky, aerobically unstable and have poor flowability properties. The first- and second-generation biofuels are highly acidic, have high moisture content and high oxygen content. Due to these properties, the pipeline system that is currently in place for distribution of fossil fuels cannot be utilized. The next-generation biofuels, referred to as drop-in fuels, are expected to have similar physical properties as fossil fuel, and thus, become interchangeable.

All the types of bioenergy will continue to face biomass feedstock transportation and other logistics challenges. Researchers are currently developing models which support large-scale biomass transportation and consequently large-scale production of bioenergy. Some of these models rely on preprocessing biomass at the farm gate, and using rail and barge as cost-efficient modes for high-volume and long-haul transportation. Some research has shown that locating a bioenergy plant close to an intermodal facility (such as, in-land port or rail station) could result in transportation cost savings. However, such a selection of a facility location may result in higher risk of disruptions due to natural disasters such as flooding. Other research has been focused on using hub-and-spoke distribution networks for biomass. These types of distribution networks have shown to be cost-efficient for airlines and railways. Similar to these industries, the products shipped on the system are widely dispersed geographically. Thus, hub-and-spoke networks could be a valid option for the in-bound supply chain design of bioenergy plants.

Ongoing concerns about bioenergy are focused not only on its economic viability, but also, on the carbon footprint in the course of its life cycle. This is because the steps involved in production and distribution of bioenergy are energy intensive. For example, growing, harvesting and transporting biomass feedstock, converting feedstock into fuel, and distributing fuel require energy. A few studies evaluate costs, energy and carbon footprint during the life cycle of bioenergy. Other studies propose models which optimize costs and emissions of the biofuel supply chain.

This handbook starts off with a survey by Balaman and Selim of existing models to optimize the bioenergy supply chain. This discussion is followed by a number of chapters which present recent developments in this area. The models developed by Chen and Huang and Poudel et al. are deterministic in nature. These models take an integrated view of facility location and transportation decisions in the supply chain.

The chapter by Kaut et al. proposes a stochastic optimization modelling framework. This modelling framework is mindful of supply and demand uncertainties which are often observed in the bioenergy supply chain. The chapter by Cinar et al. presents a two-stage stochastic model which captures uncertainty of costs and biomass supply on a supply chain design problem. A few chapters focus of single objective optimization models. Chapters by Palander et al., Zhang and Osmani present multi-objective optimization models. These models optimize costs and delivery time in the supply chain; and costs and land use. The chapter by Morales-Rincón et al. discusses a GIS-based method to locate bioenergy production facilities. Amundson et al. present a framework which integrates process optimization, supply chain optimization and discrete event simulation capabilities. Their goal is to provide a comprehensive and multidisciplinary tool for bioenergy supply chain design. The tool incorporates risk models in order to capture various uncertainties of this supply chain. Bai and Ouyang provide a comprehensive review of the impacts of bioenergy production on the transportation systems and infrastructure. The chapter by Cinar et al. reviews and classifies the literature on biomass co-firing. Grebner et al. discuss some physical and economic methods for assessing woody biomass availability for bioenergy production. Thomas et al. provide an environmental life-cycle assessment of biofuel production; and Granda-Marulanda et al. provide a life-cycle cost assessment of biofuel production using syngas.

To summarize, this handbook brings together recent advances on a number of topics which are important for the development and long-term sustainability of this industry. The handbook presents a number of models that can be used to optimize the supply chain performance of different types of biomass, such as, forest products and residues, energy crops, etc.; and different types of bioenergy, such as, cellulosic ethanol, biodiesel, electricity, etc. The case studies present problems faced by the industry in Southeast USA (such as, Alabama and Mississippi), or Western USA (such as, California) or Europe (such as, Norway and France).

February 2015

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Springer

http://www.springer.com/978-3-319-20091-0

Handbook of Bioenergy
Bioenergy Supply Chain - Models and Applications
Eksioglu, S.D.; Rebennack, S.; Pardalos, P. (Eds.)
2015, X, 343 p. 114 illus., Hardcover
ISBN: 978-3-319-20091-0